# NEW METHODOLOGY FOR SPECTRAL ANALYSES AT HIGH SPATIAL RESOLUTION: AN EXAMPLE THROUGH THE INVESTIGATION OF THE MARE HUMORUM REGION OF THE MOON.

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**Summary.** Increasing spatial resolution in remote sensing of the planetary surfaces imply to take into account, for the processing and analysis, the complex information that is provided with the recent or future hyperspectral datasets. Following (1), we have established a new methodology for the analysis of Clementine data, and tested it in the case of Mare Humorum. An extended (600 x 450 km) multispectral mosaic has been built from the Clementine UV/Visible data, with a high spatial resolution (340m) coverage. Several spectral analyses allowed us to deconvolve the compositional properties (iron abundance) from the effects of soil maturity, to derive the Ti content of the mare units, and to establish a first-order evaluation of the surface mineralogy in the studied region. In addition, the combination of the results issued from an iterative spectral mixture modeling with the geologic and topographic information has led us to some inferences concerning the emplacement and evolution of the identified units, the contamination of these units by volcanic intrusions or ejecta deposits, as well as the heterogeneities of the lunar crust in relation with the basin formation.

**Introduction.** Studied through many previous works (e.g., 2, 3, 4), the Humorum basin and its immediate surroundings constitute important areas that can contribute to a better understanding of the lunar crustal evolution. The location of this region corresponds to the interplay of both Orientale materials deposition and Oceanus Procellarum basaltic emplacement. The well-preserved geologic structures also reveal the great complexity of the region and may provide significant clues on the tectonic, volcanic, or impact processes that have modified the crustal composition and stratigraphy. With the general objective of studying in detail the optical and compositional heterogeneity of the surface in the basin region, and considering that the previous telescopic (e.g., 3, 4, 5) and SSI/Galileo (e.g., 6, 7) observations were limited in spatial resolution (several km), multispectral analyses have been performed at high spatial resolution (340m), using the Clementine UV/Visible data.

**Data Processing and Objectives.** A multispectral mosaic or image-cube has been constructed from more than 2000 raw Clementine frames in the 0.40, 0.75, 0.90, 0.95, and 1 μm wavelength channels. It covers 11 spacecraft orbits and represents more than 2.6 million spectra acquired over an extended areal coverage of 600 x 450 km (14° to 34°S in latitude, 36° to 52°W in longitude). The calibration in reflectance has been made through independent SSI/Galileo spectra of the MH0, MH40, and MH45 spots (extracted from (8)). The photometric coherence of the mosaic is estimated to be around 2%, on the basis of comparisons with Galileo or telescopic spectra acquired in the analyzed area.

The scientific objectives were to perform investigations on this mosaic in order (i) to constrain the surface properties through analyses using all the spectral and spatial information, (ii) to deconvolve in the analysis of the spectral features the effects of soil maturity from the compositional properties, (iii) to determine at first order the maturity, the iron abundance, and the titanium content (mare) of the soils, (iv) to analyze the lateral variations of the surface properties at a regional scale, (v) to determine the contamination of the units within or adjacent to the basin by materials originated from impacts or from basaltic intrusions, (vi) to examine at a more local scale the spatial variations of the spectral properties associated with fresh mare and highland craters or with tectonic structures.

**Analytical Methods.** A principal component analysis has led to the identification of 7 spectral signatures representative of the major terrain types within the studied region. With the objective of modeling the respective abundances of these identified types, a linear spectral mixture modeling has been applied to the dataset. The combination of endmembers takes into account the information of maturity and Fe content (derived from the 0.95/0.75 μm ratio versus the 0.75 μm reflectance (9)), as well as the Ti content of the mare units (derived from the empirical relation of (10)). The large number of endmembers and the requirements of spectral and geological coherence have led us to use an iterative approach. The modeling aims at explaining the overall variability present in the image-cube through successive logical combinations of several geological endmembers. It provides a better understanding of the spatial distribution of the discriminated surface units, in relation with the information of geology, topography, composition, and maturity. At each iteration, the fractional abundances estimates have to verify a number of conditions to be considered relevant to the geologic mapping and consequently, to validate the tested endmembers combination. The fractions are restricted to the interval [0,1] and the residuals are constrained to be less than 2.5% for the 0.40/0.75 μm spectral ratio and less than 2% in other channels. Unlike the simple models that are currently used, it avoids physically aberrant combinations of endmembers and allows for the analysis of complex situations likely to be met at such a high spatial resolution. The non-respect of these criteria determines the pixels or areas of the mosaic that are unmodeled by the considered combination of endmembers. Track of those pixels is kept through a mask image progressively generated with the iterations.

**Conclusions.** Our spectral investigation of the Mare Humorum region constitutes one of the first studies of an extended lunar region at such a high spatial resolution. Therefore, we have developed a new methodology in order to perform spectral analyses that are able to take into account the complexity of the studied region. It produces spectrally and spatially coherent results, with an increased reliability with respect to more simple approaches. Despite the low spectral coverage of Clementine data (5 channels), the spatial accuracy of the data and the reliability of the employed methodology allowed for powerful spectral investigations. A limited number of representative spectral behaviors has been identified. A detailed and precise mapping of the corresponding spectral units in the Humorum region has been established, and their optical/compositional properties have been related to the geologic and tectonic structures. The relevant scientific results we obtained with the application of this new methodology are presented in this volume in a companion abstract.

**Acknowledgements.** This work has been supported by the French Program National de Planétologie (INSU).

**References.** 1. Pinet, P.C. et al., Lunar and Planet. Sci. Conf., 27th, 1037-1038, 1996; 2. Pieters, C.M. et al., Proc. of the 6th Lunar and Planet. Sci. Conf., 2689-2710, 1975; 3. Lucey, P.G et al., Proc. of the 21st Lunar and Planet. Sci. Conf., 391-403, 1991; 4. Hawke, B.R. et al., Geophys. Res. Lett., 20, 6, 419-422, 1993; 5. Chevrel, S. and Pinet, P., Proc. of the 22nd Lunar and Planet. Sci. Conf., 249-258, 1992; 6. Head, J.W. et al., J. Geophys. Res., 98, E9, 17149-17181, 1993; 7. Mustard, J.F. and Head, J.W. III, J. Geophys. Res., 101, E8, 18913-18925, 1996; 8. Pieters, C.M., et al., J. Geophys. Res., 98, E9, 17127-17148, 1993; 9. Lucey, P.G. et al., Science, 268, 1995; 10. Johnson, J.R. et al., Geophys. Res. Lett., 18, 11, 2153-2156, 1991.